Acta Mineralogica-Petrographica, Szeged, XXIV/1, 41—62, 1979

PETROGRAPHY AND CHEMISTRY OF THE GRANITIC ROCKS AND THE OVERLYING NUBIAN SANDSTONES IN BIR UM HIBAL AREA, SOUTHEAST OF ASWAN, EASTERN DESERT, EGYPT

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ABSTRACT

The present work deals with detailed petrographic and chemical studies on the granitic rocks and the overlying Nubian Sandstones in Bir Um Hibal area, South Eastern Desert of Egypt.

Fort the first time, it is concluded that the porphyritic Aswan type granites are not only restricted to Aswan Province, but they extend further south, at least, till Bir Um Hibal area. The overlying Nubian Sandstones are proved to be "sublitharenites". They contain considerable amounts of rock fragments from different types; the most common of which are the granite, granodiorite and gneiss fragments. These Nubian Sandstones were most probably deposited in a fresh water environment. The detailed petrographical and chemical studies showed that the Nubian Sandstones of Bir Um Hibal area are submature (subgreywacke type) and were mostly derived from the pre-existing underlying basement rocks.

INTRODUCTION

Bir Um Hibal area lies in the South Eastern Desert of Egypt — latitude 23° 46′ N and longitude 33° 15′ E; being situated almost 60 km southeast of Aswan town *(Fig. 1)*.

This area was chosen for the present work because it can serve as a model to illustrate the relationship between the Nubian Sandstones, which occur in different types, and the underlying basement rocks.

As far as the authors are aware, no petrographical or chemical studies were carried out either on the Nubian Sandstones or on the underlying basement rocks, which are mainly granitic, in Bir Um Hibal area. Relatively few works on the geology of the Nubian Sandstones in the Eastern Desert of Egypt were carried out by some authors, i.e., ANDREW [1937], SHUKRI and SAID [1944], SHUKRI and EL-AYOUTI [1953], ABDEL WAHAB [1972], EL-HINNAWI *et al.* [1973] and EL-BADRY [1974].

ANDREW [1937], gave a detailed description on the Nubian Sandstones occurring in the Eastern Desert of Egypt. He pointed out that all the sandstones interposed between the fossiliferous carbonate rocks and the Precambrian are of upper Cretaceous age, in the region south of latitude 28° 40′ N. ANDREW attributed these sandstones to be either of local origin or derived from a southern source. Aswan area and the surroundings were considered by ANDREW as type localities where the relationship between the Nubian Sandstones and the underlying basement rocks can be illustrated. The Nubian Sandstones are generally underlain by a conglomeratic and irregular surface of the older rocks. A peculiar phenomenon pertaining to many of these Nubian Sandstones is the rare occurrence of pebbles of the underlying basement rocks, even in the lowermost layers of the sandstones.

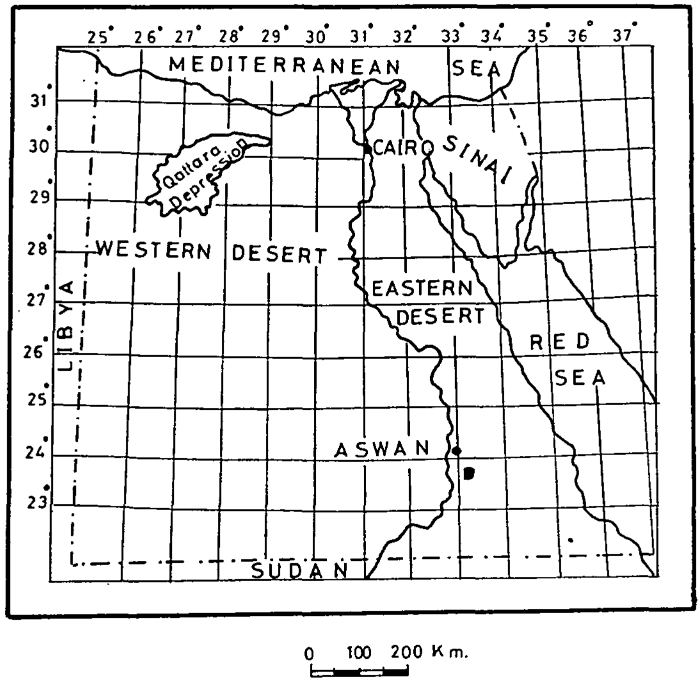

Fig. 1. Location map of the area investigated

The problem of the mode of deposition and origin of the Nubian Sandstones in Egypt has been a matter of discussion since about a century. POMEYROL [1968] has summarized most of the published views in this concern.

Regarding the basement rocks underlying the Nubian Sandstones in the investigated area, they are mainly represented by granites. As already mentioned before, no petrological or chemical studies were carried out on the granites in Bir Um Hibal area. Only some works on the regional geology, geochronology, geochemistry, and petrology of the basement rocks in Aswan province and surroundings were carried out by some workers, the most important are those of BARTHOUX [1922], HUME and HARWOOD [1925], GINDY [1954], ATTIA [1955], HIGAZY and WASFY [1956], EL-SHAZLY [1964], Hunting geology and geophysics [1967], EL-SOKKARY [1970], HASHAD *et.al.* [1972] and EL-GABY [1975].

The present paper mainly deals with the petrography and chemistry of the granitic rocks and the overlying Nubian Sandstones in Bir Um Hibal area. Also, the relationship between the two rock types is treated.

SAMPLING AND METHODS OF STUDY

Thirty two representative Nubian Sandstone samples from the different varieties were carefully collected together with sixteen granitic samples from the underlying basement rocks. It should be noted that the Nubian Sandstone samples are collected from the immediate contact with the underlying granites.

Two chips were removed from each sample, one for a thin section and the second to be stained with sodium cobalti nitrite for the determination of potash feldspar/plagioclase feldspar ratio. Of these thirty two Nubian Sandstone samples and those sixteen granitic ones, six samples from each were crushed and split for rapid rock analysis of major elements, direct-reader spectrometric analysis of trace elements and X-ray diffraction analysis of major minerals. Rapid rock analyses were performed in the Department of Mineralogy of Eötvös Loránd University, Budapest, Hungary; using the single solution wet chemical method described by SHAPIRO [1967]. Direct-reader spectrometric analyses were performed in the Department of Petrology and Geochemistry of the same University using spectrograph ISP-28 (Soviet, medium disp. with quartz optics). X-ray diffraction was carried out using Siemens Crystalloflex – 4 type diffractometer with CuK_α radiation.

PETROGRAPHY OF THE GRANITIC ROCKS

Microscopic examination of thin sections of the granitic rocks revealed that the investigated samples are nearly of the same mineralogical composition, though of variable proportions of minerals.

Petrographical description revealed that these granitic samples are holocrystalline, generally coarse-grained and subhedral. These samples are essentially composed of potash feldspars, plagioclase feldspars, quartz, biotite and sphene. The potash feldspars include microcline, microcline-microperthite and a few orthoclase. The microcline shows a characteristic cross-hatching twinning *(Fig. 2)*. The microperthites are of the film-type and they consist of small and thin streaks of plagioclase within the potash feldspar matrix. Some orthoclase is present showing simple twinning. The microcline is cracked with occasional quartz inclusions, and it sometimes contains small patches of earlier plagioclases which are in optical continuity with each other.

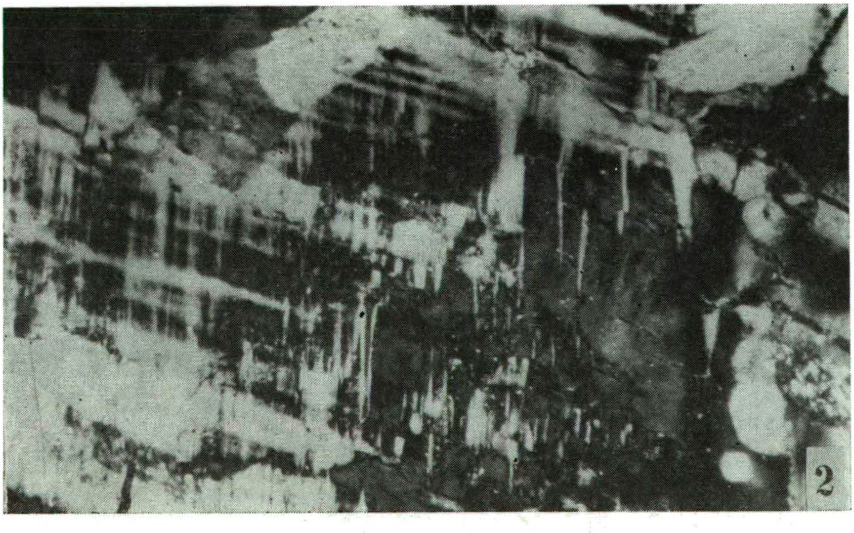

Fig. 2. Photomicrograph showing well-developed cross-hatched microcline. Crossed nicols, × 80

Plagioclase grains are mostly turbid, cracked, highly weathered and sericitized *(Fig. 3)*. It is observed that the degree of weathering in the plagioclase grains is more conspicuous at their interior parts, thus giving a sort of zoning of highly and slightly weathered bands in the plagioclase grains. Lamellar twinning is very clear, especially at the margins of the plagioclase grains and the twin lamellae are thin. The plagioclase may exhibit patchy extinction, which may indicate strain in such grains. Mostly, the plagioclase is an oligoclase. It is to be mentione that the investigated granitic rocks are characterized by the occasional occurrence of myrmekitic exture *(Fig. 4)*.

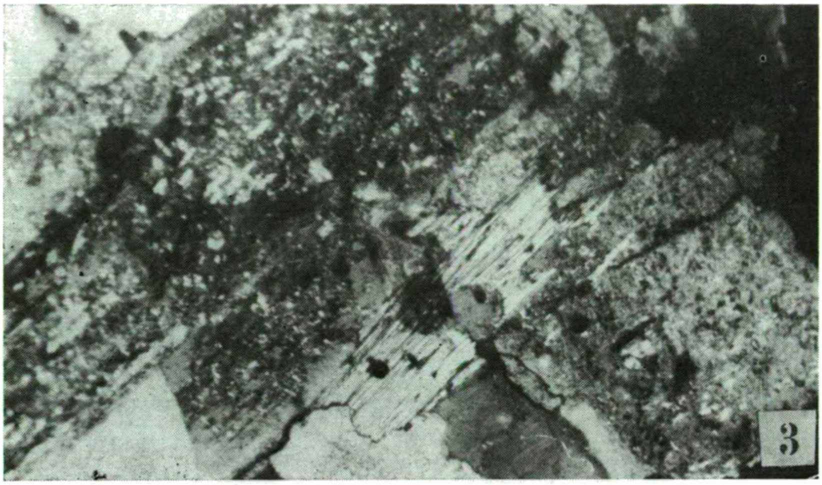

Fig. 3. Photomicrograph of intensively weathered plagioclase. The cores are more weathered. Crossed nicols, × 70

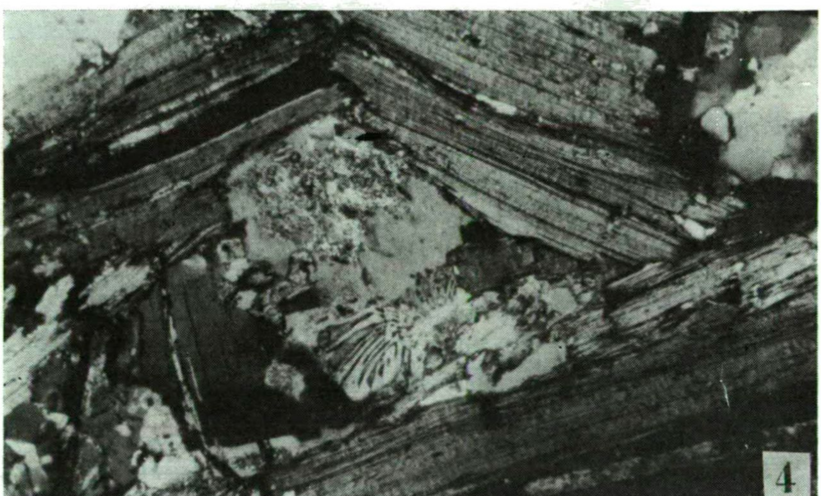

Fig. 4. Photomicrograph showing myrmekitic texture. Crossed nicols, × 54

Quartz is usually anhedral and occasionally shows strong undulose extinction. Biotite is relatively abundant and shows distinct pleochroism from yellowish brown to deep brown. Some of the biotites are partially chloritized and bent *(Fig. 5)*.

Hornblende is occasionally found in some thin sections, exhibiting its characteristic cleavage in granite *(Fig. 6)*. Accessory minerals include opaque minerals (mostly brown iron oxides), sphene with the characteristic wedge-shaped crystals, while zircon and apatite are found but to a less extent.

Modal analysis of selected six granitic samples, aided by the stained chips with sodium cobalti nitrite was carried out. The data are given in Table 1 and are illus-

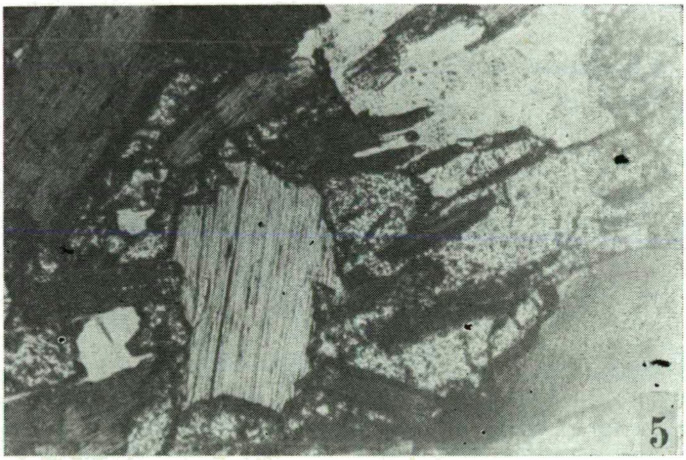

Fig. 5. Photomicrograph showing biotite flakes partially chloritized and bent. Crossed nicols, × 54

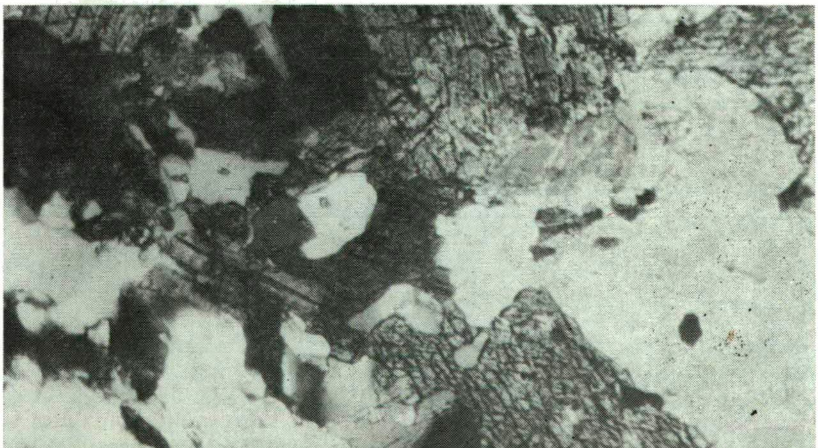

Fig. 6. Photomicrograph showing hornblende crystals with the characteristic cleavage in granite Crossed nicols, × 80

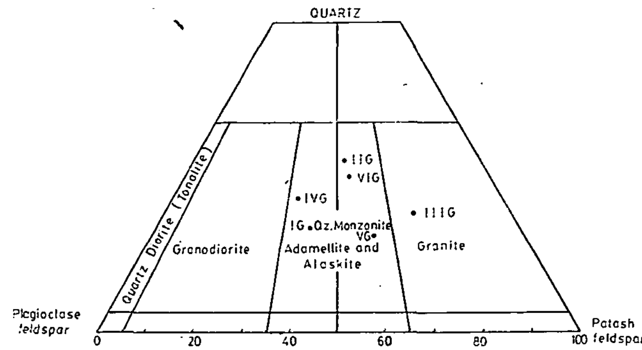

Fig. 7. Modal analysis of the studied granitic samples plotted quartz — plagioclase feldspar — potash feldspar ternary diagram

trated on quartz-plagioclase feldspar-potash feldspar ternary diagram *(Fig. 7).* It is shown that samples I G, II G, IV G, V G and VI G fall in the adamellite field, though samples I G and IV G have granodioritic tendencies. Sample III G is of granitic composition.

It should be mentioned that the petrography of the studied granitic rocks given here is very similar to the petrography of the typical Aswan coarse granites as given by EL-SOKKARY [1970].

TABLE 1

Modal composition of the studied granitic samples

Constituent \ Sample No.	I G	II G	III G	IV G	V G	VI G
Quartz	21.83	36.56	22.22	28.13	20.96	32.94
Potash feldspar	27.71	28.04	41.62	23.18	40.13	30.15
Plagioclase feldspar	36.84	25.46	15.79	37.51	26.96	25.12
Biotite	9.50	9.80	7.00	11.00	8.02	9.40
Hornblende	—	—	10.37	—	—	—
Opaque minerals	1.24	—	—	—	—	—
Others (apatite, zircon)	0.20	0.14	0.11	0.18	1.0	0.14
Chlorite	2.20	—	2.89	—	2.93	2.25
Sericite	0.48	—	—	—	—	—

CHEMISTRY OF THE GRANITIC ROCKS

Major Elements

Table 2 illustrates the data of chemical analyses of the major elements for the six granitic samples. The data are compared with the corresponding data of the low-calcium and high-calcium granites given by TUREKIAN and WEDEPOHL [1961]. Also the data are compared with the average analysis of a typical pink porphyritic granite from Aswan [EL-SOKKARY, 1970].

It is shown that samples I G, II G, IV G, V G, and VI G are not precisely identical either with the low-calcium or with the high-calcium granites. Thus these

TABLE 2

Chemical analysis of the studied granitic samples

Oxide	I G	II G	III G	IV G	V G	VI G	A	B	C
SiO_2*	71.18	71.55	61.18	73.01	70.99	70.05	74.29	67.23	70.29
Al_2O_3	12.80	13.14	18.84	11.99	12.83	13.85	13.61	15.50	13.79
Fe_2O_3	1.65	1.99	2.15	1.05	1.83	1.00	2.03	4.23	0.43
FeO	2.59	3.15	4.00	0.63	2.19	3.09	—	—	2.00
MgO	0.63	0.83	1.20	0.93	0.73	0.93	0.27	1.56	1.10
CaO	2.15	1.00	1.75	2.00	1.95	2.13	0.71	3.54	1.24
Na_2O	3.05	2.40	4.05	3.69	3.43	3.68	3.48	3.83	3.00
K_2O	4.65	5.05	5.53	4.08	5.00	4.85	5.06	3.04	6.00
TiO_2	0.63	0.43	0.70	0.87	0.67	0.46	0.20	0.57	0.60
MnO	0.05	0.06	0.03	nil	0.01	0.03	0.05	0.07	0.06
P_2O_5	0.25	0.34	0.35	0.45	0.65	0.45	0.14	0.21	0.15
Total	99.63	99.94	99.78	98.70	100.28	100.53	99.64	99.36	98.66

*: Analyst, HAFEZ S. ABDEL WAHAB
**: Represents total iron.
A: Low-calcium granite (TUREKIAN and WEDEPOHL, 1961].
B: High-calcium granite [TUREKIAN and WEDEPOHL, 1961].
C: Average pink porphyritic granite of Aswan [EL-SOKKARY, 1970].

five samples have SiO_2, MgO and CaO contents which are intermediate between the two reference granites of TUREKIAN and WEDEPOHL. K_2O and MnO are distributed according to the low-calcium granite, while Fe_2O_3, TiO_2 and P_2O_5 are distributed according to the high-calcium granite. By comparing the data of the five samples with the average analysis of the pink porphyritic Aswan granites [EL-SOKKARY, 1970], it is found that the two sets are generally in a close accordance.

Sample III G is generally conformable in chemical composition with the high-calcium granite. However, SiO_2 content is notably lower than the high-calcium granite and K_2O is much higher.

The modal analysis of sample III G indicates a high potash feldspar/plagioclase feldspar ratio, and allocates it in the granite field *(Fig. 7)*. The X-ray diffraction pattern showed this sample with a potash feldspar/plagioclase feldspar ratio less than one. This may be tentatively attributed to the micro- or cryptoperthitic nature of the potash feldspars in sample III G.

The authors are of the opinion that the potash feldspar/plagioclase feldspar ratio as given by X-ray diffraction is more reliable and more conformable with the chemical analysis. The modal analysis of sample III G with a high potash feldspar content can be interpreted on the basis that white micas and clay minerals (as intensive alteration product of plagioclase) may absorb sodium cobalti nitrite stain, thus giving rise to a false-high potash feldspar content [DEER *et.al.,* 1963]. Moreover, the high sericitization of the plagioclase in this sample may be responsible for the fixation of extraneous K_2O and consequently increase of K_2O content in sample III G.

Generally, the chemical composition of the investigated granitic samples are correlated with Aswan coarse granites and it is revealed that most of them are similar in chemical composition.

Trace Elements

Table 3 illustrates the contents of 14 trace elements (in ppm) in the six granitic samples. The data are compared with the corresponding data of the low and high-calcium granites given by TUREKIAN and WEDEPOHL [1961]. Also the data are compared with the coarse pink porphyritic granites of Aswan [EL-SOKKARY, 1970].

From trace elements point of view, the investigated granites do not follow either the low or high-calcium granites. It is found that the elements Ba, Cr, Ni, V and Cu are distributed according to the low-calcium granite, while Co and Zn are distributed according to the high-calcium granite. B and Sr take intermediate distributions between the two reference granites. This adds to the peculiar character of these granitic rocks as already revealed from the elemental distribution of both major and minor elements.

Sample III G shows enrichment in B, Zn and Sb, a matter which may be attributed to the concentration of these elements, particularly B and Zn in amphiboles which are notably abundant in this sample [see GOLDSCHMIDT, 1962].

The distribution of trace elements in the investigated granitic samples shows some similarities with those of Aswan granites, especially in the distribution of Sr, Ga, Ni, V and Cu. This again assures that the studied granites from Bir Um Hibal area are similar to the typical pink Aswan granites.

TABLE 3

Trace elements (ppm) in the investigated granites

Sample No.	B	Ba	Sr	Ga	Be	Co	Cr	Ni	V	Cu	Pb	Zn	Sb	W
I G	10	790	160	20	< 10	< 10	9	< 10	42	10	< 10	60	< 160	< 100
II G	12	680	180	22	< 10	10	6	11	17	15	< 10	130	< 160	200
III G	19	750	210	15	< 10	13	6	< 10	15	13	< 10	160	160	< 100
IV G	< 10	470	110	19	10	< 10	5	12	40	16	30	50	< 160	< 100
V G	14	900	180	60	< 10	10	8	< 10	30	19	44	80	< 160	< 100
VI G	< 10	600	100	25	< 10	10	< 3	< 10	16	10	41	40	< 160	< 100
L.D.	10	100	100	1	10	10	3	10	10	10	10	40	160	100
A	10	840	100	17	3	1	4	5	44	10	19	39	0.2	2.2
B	9	420	440	17	2	7	22	15	88	30	15	60	0.2	1.3
C	—	1350	209	21	4	3	1	3	25	8	19	—	—	—

L.D.: Limit of detection (ppm).
—: Not detected.
A: Low-calcium granite [TUREKIAN and WEDEPOHL, 1961].
B: High-calcium granite [TUREKIAN and WEDEPOHL, 1961].
C: Average coarse pink porphyritic granites of Aswan [EL-SOKKARY, 1970].

The Nubian Sandstones in Bir Um Hibal area are generally semi-friable and friable, however, compact beds are occasionally found. These sandstones have different shades of colours; yellow, buff, grey and brown. When the thin weathered layers are removed, the sandstones appear yellowish in colour.

The Nubian Sandstones in the investigated area exhibit a number of primary structures. The most important is stratification; following the terminology of McKEE and WIER [1953], the main type encountered is the tabular planar and to less extent are the dipping tabular planar and the truncated wedge cross strata types. Also, graded bedding and the asymmetrical ripple marks are recorded in some exposures.

Microscopic examination of 32 thin sections revealed that the Nubian Sandstones of Bir Um Hibal area consist mainly of quartz. Beside the quartz grains, rock fragments, feldspars, hematite, calcite, dolomite, gypsum, micas and clay minerals are found.

The roundness of the quartz grains vary from subangular to rounded. Well rounded grains are next in abundance, while angular and very angular grains are very subordinate in amount. This may be attributed to the fact that the Nubian Sandstones near the basement complex (our investigated area) represent a shoreline type of sandstone, where the sand grains were subjected to strong effects of back and forth rolling and rounding.

Generally, these sandstones are moderately well sorted and they mostly have sizes between 0.20 and 1.0 mm.

The *quartz* grains are mostly polycrystalline "composite" and to less extent monocrystalline "single". Both types may have undulose extinction *(Fig. 8)* and

Fig. 8. Photomicrograph showing polycrystalline quartz grains with clear sutures and undulose extinction. Crossed nicols, × 56

may show overgrowths *(Fig. 9)*. The pore spaces between the quartz grains are partially and/or completely filled with a variety of matrices and cements. The most frequent are hematite, kaolinite, calcite, chert, gypsum, opal and chalcedony.

The quartz grains are mostly cemented by *iron oxides* (hematite). The irregular contact between the quartz grains and the hematitic cement indicates that the depo-

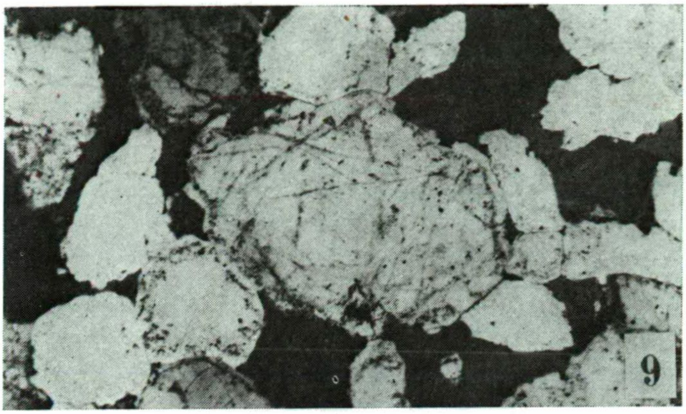

Fig. 9. Photomicrograph of silica cemented Nubian Sandstone. Quartz grains show overgrowth. Crossed nicols, × 16

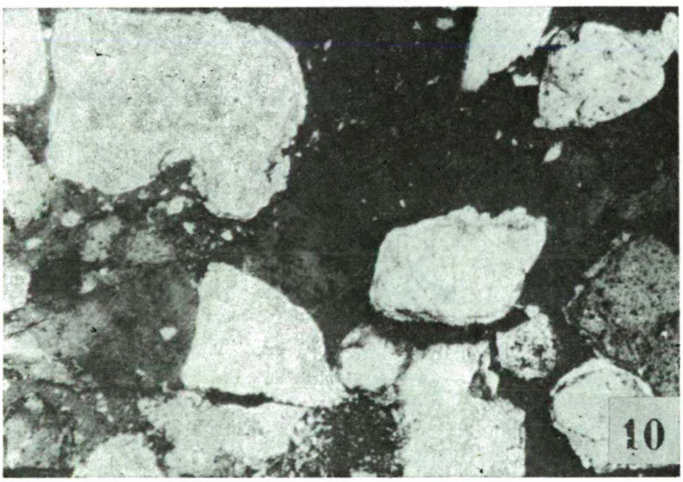

Fig. 10. Photomicrograph of Nubian Sandstone cemented by hematite. Note the irregular contact between the quartz grains and the hematitic cement. Crossed nicols, × 16

sition of the cementing material took place syngenetic or just later *(Fig. 10)*. The main source of ferric oxides in the Nubian Sandstones was in-place alteration of iron rich minerals.

Clay minerals as a matrix is mainly kaolinite (as revealed from the X-ray diffraction). The abundance of kaolinite indicates humid tropical weathering conditions in the source area [DAPPLES, 1967]. It is observed that kaolinite is usually associated with chert in the matrix between the quartz grains *(Fig. 11)*.

Carbonate cement is common in many of the studied sandstones, thus calcite and dolomite (as revealed microscopically and from X-ray diffraction) are abundant cementing materials *(Fig. 12)*.

Chert is also precipitated in the matrix thus giving rise to a cherty sandstone *(Fig. 13)*. Precipitation of chert in the matrix is an early locomorphic process [DAPPLES, 1967]. *Gypsum* has been observed partly filling the interspaces between the

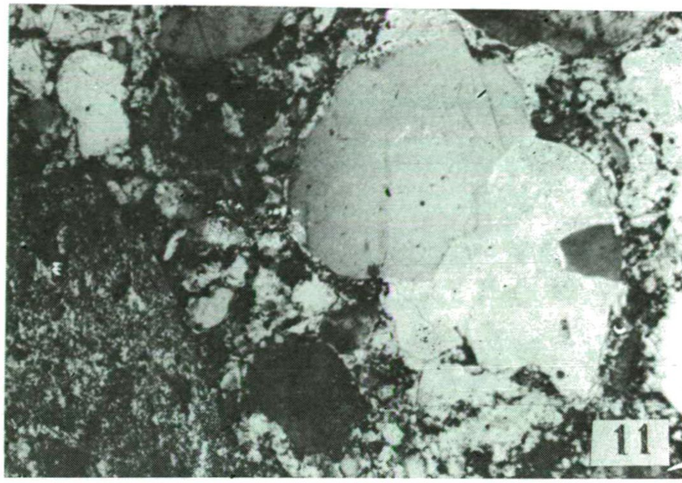

Fig. 11. Photomicrograph showing polycrystalline quartz grain together with single ones set in a hematite-kaolinite matrix. Crossed nicols, × 56

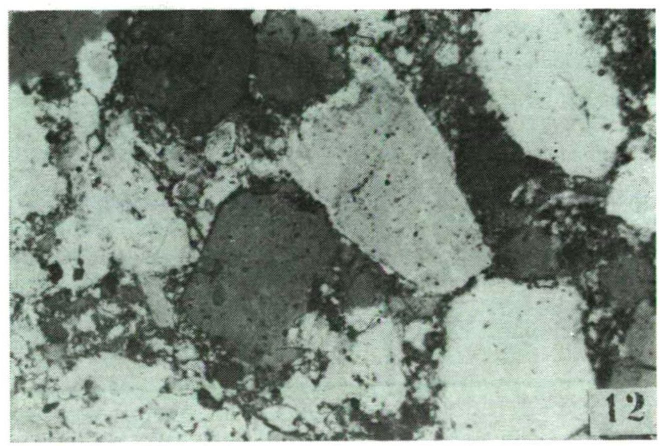

Fig. 12. Photomicrograph showing subrounded detrital quartz cemented by carbonate (calcite and dolomite) and partly by chert-kaolinite matrix. Note the sprinkled dolomite rhombs within the calcite cement. Crossed nicols, × 56

quartz grains *(Fig. 14)*. The occurrence of gypsum is to be related to evaporite conditions at the time of sedimentation or to the movement of hypersaline pore waters from an overlying evaporite formation [see, for example, MURRAY, 1964].

Opal and *chalcedony* are also observed to fill the pore spaces between quartz grains. Quartz is only found adjacent to chalcedony which always separates quartz from opal *(Fig. 14)*.

The Nubian Sandstones of Bir Um Hibal area are characterized by abundance of rock fragments (9%), mainly granite, gneiss, schist, granodiorite, chert, siltstone and quartzite *(Figs. 16* and *17)*.

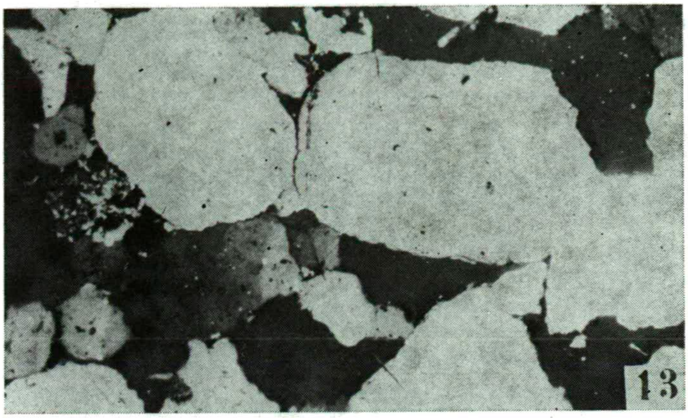

Fig. 13. Photomicrograph showing chert filling the pore spaces between the quartz grains. Crossed nicols, × 80

Fig. 14. Photomicrograph showing scattered gypsum between the quartz grains. Crossed nicols, × 24

It is found that the granitic fragments sprinkled within the lowermost horizons of the Nubian Sandstone beds are largely correlated with the underlying granitic rocks of Bir Um Hibal area. This may be taken as a proof for the derivation of these Nubian Sandstones from the pre-existing underlying basement rocks.

PARAGENETIC RELATIONS OF CEMENTING MATERIALS

It is agreed that the diagenetic modification of sands following deposition occur as progressive stages. *Redoxomorphic* (oxidation-reduction) *reactions* involving iron in particular characterize early burial. *Locomorphic changes* (cementation and mineral replacement) involving primarily silica and carbonates are typical of lithification. The *phyllomorphic stage* (authigenesis of micas and feldspars) is a late burial feature.

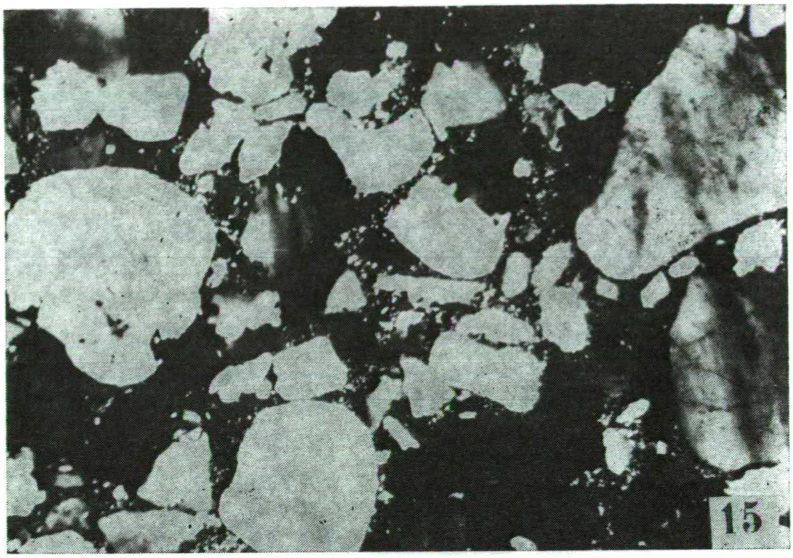

Fig. 15. Photomicrograph showing chalcedony filling the pore spaces between quartz grains; the latter are separated from opal by chalcedony. Crossed nicols, × 16

Fig. 16. Photomicrograph of Nubian Sandstone with rock fragments mainly of granite and chert. Crossed nicols, × 16

Chemical reactions which occur during each of the three stages of diagenesis result in equilibrium mineral assemblages which are considered to identify the pH and Eh of the interstitial fluids.

Petrographical studies of the Nubian Sandstones of Bir Um Hibal area showed the latter to contain different diagenetic features. The paragenetic sequence of them can be explained as in the following.

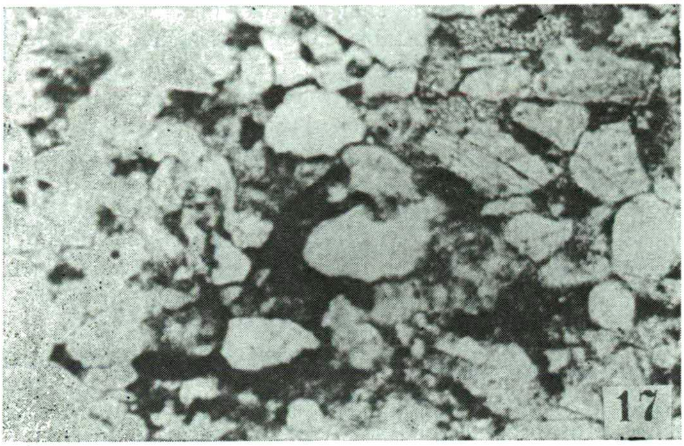

Fig. 17. Photomicrograph showing Nubian Sandstone with granodioritic rock fragments; note the occurrence of feldspars with traces of cleavage. Crossed nicols, × 16

Redoxomorphic Changes

As described in the petrographical discussion, the quartz grains are seen to be isolated or "floating" in the hematitic cement *(Fig. 10)*. This texture only originates as a result of pore filling by hematite. This situation may exist during which the burial environment is oxygenated by contact with atmosphere and iron oxides arrive as part of the detritus. In the burial environment oxygen gathers electrons principally donated by iron to form hematite and related ferric oxides or hydrates, which along with those having arrived as part of the detritus, remain stable [DAPPLES, 1967]. In some thin sections, it is observed that the matrix is composed of mixtures of clay minerals (kaolinite, as revealed from X-ray diffraction) and hematite *(Fig. 11)*, such a mixture is modified only a result of differential compaction between the sand and clay sizes.

According to DAPPLES [1967], the nature of the clay-cemented sandstones is primarily a surface film phenomenon and attains its greatest tensile strength when clay dries. Ideally, cementation of this type does not involve precipitation of mineral matter.

The source of clays in the investigated Nubian Sandstones is mostly resulted from the decomposition of feldspars in the sediment, as it is observed that some kaolinitic grains preserve the outline of the original detrital feldspar grain.

Locomorphic Changes

The reaction tendencies of the locomorphic stage can be classified as one of three types; namely: *(1)* transition from a metastable mineral phase into a more stable form primarily as a function of time; *(2)* solution of one mineral and precipitation of another as a result of change in solubilities with change in pH or temperature of permeating waters; and *(3)* shift in an equilibrium assemblage with change in pH, temperature and oxidation potential.

The unidirectional reaction: opal → chalcedony → quartz is a very good illustration of the first type. The disordered opal lattice becomes increasingly ordered in time and is replaced by either fibrous chalcedony or chert. Once the chert is formed, the silica has achieved a relatively stable condition which is not perceptibly altered by moderate increase in pressure or temperature due to deep burial. Precipitation of chert in the matrix normally is an early locomorphic process.

Replacement of interstitial clay by chert can be taken as an event of the locomorphic stage. This may be explained by the fact that silica may be released and reprecipitated in the form of chert. Such chert is accommodated in the interstitial space by crowding or engulfing the detrital clay minerals present.

Precipitation of secondary quartz as overgrowths and filling the interstitial spaces *(Fig. 9)* can be currently attributed to the so called zones of quartz enlargement or "case hardening" of outcrop surfaces. This precipitation appears to be favoured by supersaturation of solutions bearing silica, such as develop from surface or underground waters leaching silicate rocks [see, KELLER and REESMAN, 1963].

Calcite is one of the dominant cement among the investigated Nubian Sandstones. The precipitation of calcite is directly associated with the instability of chert and quartz. Some years ago, the antipathetic reaction between quartz and calcite was attributed by CORRENS [1950] to the inverse relation in solubility with change in pH. Calcite decreases in solubility and silica becomes more soluble as the pH is elevated. The occurrence of replacement of quartz by calcite in the Nubian Sandstones of Bir Um Hibal area suggest that shift in pH is very important in this locomorphic process despite the very small differences in solubility. Also, the local changes in the partial pressure of CO_2 resulting from temperature differences near the outcrop are considered to be the direct cause of change in pH values.

In some thin sections, it is observed that the clay matrix may be replaced by calcite *(Fig. 12)*. The mechanism of such replacement is not fully understood, but it appears that the clay mineral kaolinite is flocculated by Ca-ion and occupies less interstitial pore space allowing the remainder to be filled with the precipitated calcite [see EDES and GRIM, 1960]. Within the calcite cement, it is observed that few rhombs of dolomite are sprinkled *(Fig. 12)*. It seems that the amount of available magnesium tends to be insufficient to permit the crystallization of large amounts of dolomite; and the common occurrence is in the form of individual rhombs within masses of calcite. This occurrence suggests that the dolomite may possibly represent some exsolution phenomenon rather than the result of introduction of magnesium from some outside source.

MODAL ANALYSIS

The last two decades witnessed a flow of papers on sandstone classification. Nearly 50 schemes of sandstone classifications have been proposed by different authors; a review of these schemes is given by HUCKENHOLTZ [1963], KLEIN [1963], SHUTOV [1965], OKADA [1971] and PETTIJOHN *et al.* [1973]. Most of the methods depend upon the percentage of quartz, feldspars and rock fragments in the sandstone.

The average modal analysis of the Nubian Sandstones of Bir Um Hibal area was calculated from counts made on several thin sections. The number of counts was sufficiently high to give a reasonable accuracy [see EL-HINNAWI, 1966].

The average results obtained are given in the following:

Quartz	*Feldspars*	*Rock fragments*
86%	5%	9%

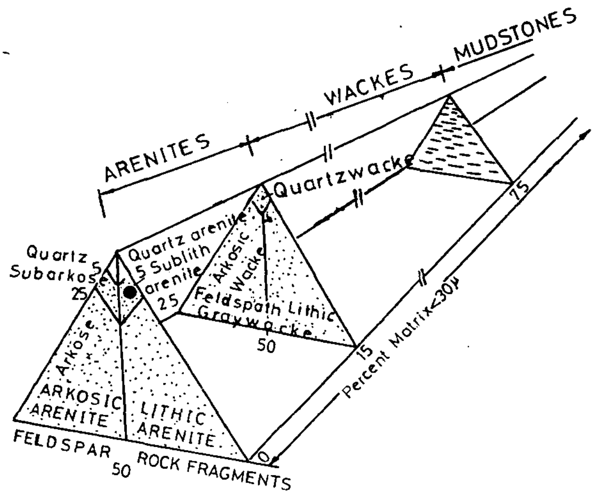

Fig. 18. Classification of terrigenous sandstones (after PETTIJOHN *et. al.*, [1973]).
● represents the Nubian Sandstones of Bir Um Hibal area

It should be noted that chert is grouped with rock fragments and not with quartz as recommended by OKADA [1971].

Applying these data to the schematic classification proposed by PETTIJOHN *et al.* [1973], the Nubian Sandstones of Bir Um Hibal area are accordingly classified as "sublitharenites" *(Fig. 18)*.

CHEMISTRY OF THE NUBIAN SANDSTONES

Major Elements

The bulk chemical composition of a sandstone is normally a function of the composition of the source rocks, the nature and maturity of the weathering processes, the effectiveness of the winnowing or washing out of the finest weathering products, the quantity and nature of the introduced cements and other changes during diagenesis and the presence or absence of biochemical or other contaminants.

In the present work, six representative Nubian Sandstone samples were chemically analysed. The results of chemical analyses are given in Table 4.

The most important chemical characteristics of the investigated Nubian Sandstones can be outlined in the following.

1. Silica percentage varies from 77.83 to 81.03. The abundance of silica content is practically valueless for any indication of the pre-diagenetic history of sandstones, as silica may be introduced during the diagenetic processes.
2. Alumina percentage varies from 7.95 to 9.18. The comparatively high content of Al_2O_3 is mainly attributed to the presence of clay minerals, micas and feldspars.
3. The presence of iron has no valuable importance as its presence is not only controlled by its provenance but largely affected by the diagenetic phases.
4. It is observed that MgO exceeds CaO in all studied samples. However, the pet-

TABLE 4

*Chemical analyses of the studied Nubian Sandstones**

Oxide	I S	II S	III S	IV S	V S	VI S
SiO_2	79.13	80.00	77.83	78.72	79.14	81.03
Al_2O_3	8.35	8.21	9.03	9.18	8.14	7.98
Fe_2O_3**	2.19	2.03	3.01	2.31	3.10	2.05
MgO	3.40	3.18	3.33	3.18	2.11	3.00
CaO	2.18	2.05	1.38	1.98	2.00	1.64
Na_2O	0.41	0.51	0.63	0.61	0.40	0.26
K_2O	0.60	0.71	0.42	0.84	0.63	0.49
H_2O^+	0.50	0.73	0.82	0.89	0.86	0.54
TiO_2	0.54	0.47	0.99	0.77	0.99	0.80
P_2O_5	0.03	0.09	0.10	0.08	0.02	0.04
MnO	0.01	nil	nil	0.01	nil	nil
CO_2	2.14	2.05	2.60	1.58	2.00	2.54
Total	99.48	100.03	100.14	100.15	99.39	100.37

* Analyst, HAFEZ S. ABDEL WAHAB.
** Represents total iron.

rographical studies revealed that calcite is the main carbonate cementing material, while dolomite is very subordinate and found only as scattered rhombs within calcite. Therefore, the abundance of Mg is not only attributed to the presence of dolomite, but largely to the alteration of ferromagnesian minerals present in these sandstones.

5. The alkali elements Na and K are mainly found in the feldspars, the Na_2O/K_2O ratio (less than 1 except sample №. III S) means that the albitization in the feldspars — if any — is of a very limited extent. This indicates that these Nubian Sandstones were not affected by later solutions bearing sodium.
6. Titanium is mainly found in clays, and in some recorded heavy minerals.

Chemically speaking, these Nubian Sandstones are generally homogeneous in chemical composition and that they are related to the "sublitharenite" [PETTIJOHN *et.al.,* 1973], after making some allowance for diagenetic effects.

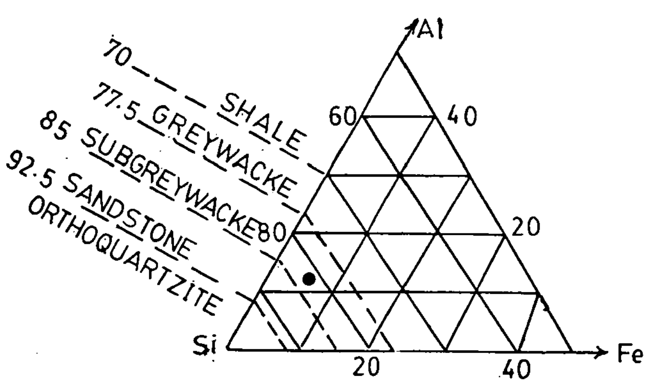

Fig. 19. Ternary plot of atomic Si—Al—Fe ratios of Nubian Sandstones of Bir Um Hibal area. ● represents the average

Fig. 19 illustrates the ternary plot of the atomic percentages of Si—Al—Fr ratios of the Nubian Sandstones in Bir Um Hibal area. From this figure it is cleae that these sandstones are submature and are of "subgreywacke" type [according to the terminology given by MOORE and DENNEN, 1970].

Is is found that the Nubian Sandstones are similar in chemical composition to those of Kalabsha area, southwest of Aswan [ABDEL WAHAB, 1976]. The slight variation in the chemical composition between them is mainly attributed to the local diagenetic processes.

Trace Elements

Table 5 gives the abundance of 14 trace elements (ppm) in the investigated Nubian Sandstones. Admittedly, trace elements data of Nubian Sandstones are quite meagre, and as such data accumulate, better understanding of this huge formation will be achieved.

Out of the reported fourteen trace elements, eleven of them, namely: B, Be, Co, Ga, Pb, Sb, Sr, V, W, Zn, and Ni are almost always below detection limit. Only Ba, Cr and Cu show variable quantities above the detection limit. It is possible to say that the studied Nubian Sandstones are depleted with respect to many trace elements.

Boron content in the investigated Nubian Sandstones is below 10 ppm which reflects a real impoverishment in this element. The source of boron may be in tourmaline grains or it may be associated with kaolinite. If it is assumed that boron is wholly attributed to the clay fraction in the present sandstones, its dropping quantities may indicate a fresh water environment of deposition [KEITH and DEGENS, 1959].

The general depletion of Ba and Sr in the present sandstones reflects the fact that they are feldspar-poor sandstones. The variable dropping quantities of Cr may be due to the presence of rare grains of chromite or it may be associated with the clay mineral (kaolinite) in these sandstones. The trace element Cu indicates that these sandstones were derived from a non-mineralized source province. The range of Cu in the Nubian Sandstones (10—21 ppm) is very close to the range of Cu content in the underlying granites (10—19 ppm).

THE RELATION BETWEEN THE NUBIAN SANDSTONES AND THE UNDERLYING GRANITES

At Bir Um Hibal area, the Nubian Sandstone lies on an irregular surface of Precambrian granitic rocks. The top part of these granitic rocks is highly weathered into kaolin, the latter is overlain by a nearly horizontal conglomeratic bed. This indicates that the granitic rocks were subjected to intensive weathering prior to the deposition of the overlying Nubian Sandstone.

The conglomeratic bed occurring at the contact between the Nubian Sandstone and the underlying granitic rocks is mainly composed of pebbles of quartz, quartzite and grit. The present authors record the occurrence of pebbles of granite, schist, gnei ss andgranodiorite disseminated within the conglomeratic bed. Also, these types of igneous and metamorphic pebbles are rarely seen to be scattered in the lowermost horizons of the Nubian Sandstone beds. The occurrence of these pebbles with this type of distribution is a very good indication to postulate that the Nubian Sandstones in Bir Um Hibal area which are submature in nature were most probably derived from the pre-existing underlying basement rocks.

TABLE 5

Trace elements (ppm) in the investigated Nubian Sandstones

Sample No.	B	Ba	Sr	Ga	Be	Co	Cr	Ni	V	Cu	Pb	Zn	Sb	W
I S	<10	100	<100	<1	<10	<10	4	<10	<10	10	<10	<40	<160	<100
II S	<10	100	<100	<1	<10	<10	7	<10	<10	21	24	<40	<160	<100
III S	<10	150	<100	<1	<10	<10	9	10	<10	15	<10	<40	<160	<100
IV S	<10	180	<100	<1	<10	<10	6	10	<10	12	<10	<40	<160	<100
V S	<10	100	<100	<1	<10	<10	6	<10	<10	10	<10	<40	<160	<100
VI S	<10	130	<100	<1	<10	<10	6	<10	<10	13	<10	<40	<160	<100
L.D.	10	100	100	1	10	10	3	10	10	10	10	40	160	100

L.D.: Limit of detection.

DISCUSSION AND CONCLUSIONS

The present studies showed that the granitic rocks of Bir Um Hibal area are mainly of adamellitic composition and they are similar in the petrography to the porphyritic Aswan granites, which are considered to be an independent granitic province. The chemical analyses of both major and trace elements showed that the investigated granitic rocks have intermediate composition between the high and low-calcium granites. At the same time, they are correlated with the porphyritic Aswan granites. This led the present authors to postulate that the porphyritic Aswan granites are not only restricted to Aswan province, but they extend further south, at least, till Bir Um Hibal area.

The Nubian Sandstone beds overlying the granitic rocks are generally medium in size, moderately well-sorted and submature sandstones. The petrographical modal analysis as well as the chemical analysis allowed the classification of these sandstones as "sublitharenites". These "sublitharenites" are characterized by the presence of different types of rock fragments, mainly granite, gneiss, granodiorite, chert, siltstone and quartzite. The granitic fragments disseminated in the Nubian Sandstones are correlated with the underlying granitic rocks. This may be taken as indication for the derivation of the Nubian Sandstones from the underlying basement rocks.

The copper content in the Nubian Sandstones proves that they were derived from a non-mineralized source province. Indeed, the Cu content in the underlying granites is very close to that in Nubian Sandstones.

Concerning the possible environment of deposition of the investigated Nubian Sandstones, it is found that the dropping boron content may indicate a fresh water environment of deposition for these sandstones.

In summary, the field relations between the Nubian Sandstones and the underlying granitic rocks in Bir Um Hibal area as well as the petrographical and chemical studies of both the two rock types favour the idea that the Nubian Sandstones represent derivation products from the underlying basement rocks, similar to the Nubian Sandstones of the nearly Aswan area.

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Manuscript received, March 1, 1979

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